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# A High-Gain Cell Enhancer

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## Abstract

Cell enhancers, or broadband on-frequency repeaters (OFRs), offer radio network operators a cost-effective means of improving service quality in areas of low signal strength, or even extending coverage into new areas. Their ability to simultaneously receive and transmit in the same frequency band provides maximum spectral efficiency and renders them transparent to the rest of the network. For stable operation however, the repeater's receiver and transmitter must be isolated by a factor greater than its active gain. The maximum gain of current cell enhancers is limited by relatively low transmitter/receiver isolation, while output powers are limited by the poor linearity of the multi-channel amplifier. In situations where high gain and/or high output powers are required, novel solutions must be sought. An enhancer offering these features is under development at the University of Bristol.

## Introduction

On-frequency repeaters (OFRs) provide an important means of enhancing the service quality of any mobile radio network. Their mode of operation renders them transparent to the rest of the network, and so provides a relatively cheap and easy means of extending radio coverage into new or badly shadowed areas. This is in contrast to conventional frequency-translating or demodulating repeaters, which are spectrally inefficient.

Figure 1 represents three different ways of supporting a full-duplex link between a base station and a mobile. The 'normal' situation is for the mobile and base to communicate directly on two simplex channels, Ch.1 & Ch.2. If the mobile now moves into an area served by a frequency-translating repeater, two additional simplex channels (3 & 4) are required to support the link. If an on-frequency repeater were employed instead, no further channels are required, and there is no need for any mechanisms to control hand-off and hand-back.

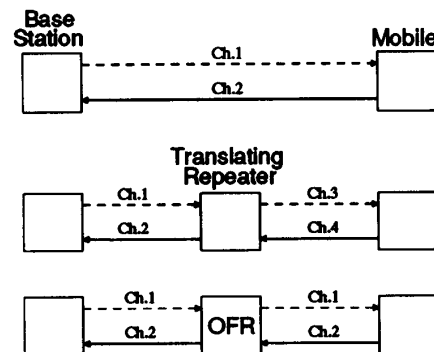


Figure 1: Channel Allocation in Repeater Systems

Repeaters may be grouped into two distinct categories: those that provide amplification for a single channel and those that boost multiple channels. The latter group may be further subdivided into repeaters that provide multi-channel operation by summing the output of many single-channel boosters using a high-power combiner (here designated Class I repeaters), and those that boost a contiguous group of channels using a single linear multi-channel amplifier (Class II repeaters).

Single-channel repeaters are of little use in the context of multi-user mobile radio networks so are considered no further here except as the component parts of Class I multi-channel repeaters.

A complete bi-directional repeater consists of two broadband amplifiers (Class II) or sets of amplifiers (Class I), one for the forward link and the other for the reverse link.

Of the two methods of providing multi-channel operation, Class I is less efficient and physically larger than its Class II counterpart, with one power amplifier per channel and a large, inefficient mechanical combiner. Also this combiner is tuned to a fixed frequency band, and

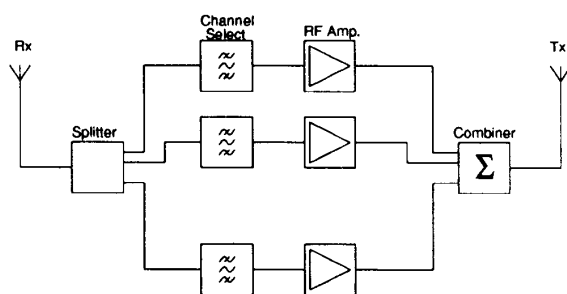


Figure 2: Class I Multiple-Channel OFR

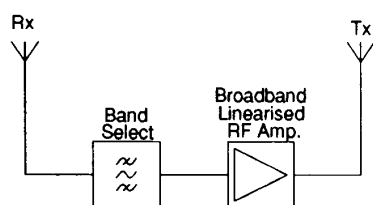


Figure 3: Class II Multiple-Channel OFR

each amplifier is tuned to a fixed channel, reducing the repeater's flexibility. Only a Class II broadband linear repeater offers the flexibility to boost an arbitrary number of channels of any given modulation. Such a repeater should also be compact, low-loss and power-efficient.

## Linearity

Class II systems must be highly linear in order to maintain intermodulation distortion at acceptable levels. To date the linearity problem has been largely avoided, using fairly linear amplifiers operating well below their compression point in order to keep intermodulation products 40dB or more below the desired signals [1]. With the introduction of linearised high-power broadband amplifiers however, such linearity constraints are easily met. Amplifiers offering third-order intermodulation products suppressed by 70dBc, with output powers of several watts have been demonstrated [2] and should soon be widely available.

## Antenna Isolation

A major problem encountered in the design of any OFR is that of ensuring sufficient isolation between the transmitter and receiver for stability. The isolation is required to be greater than the repeater's electrical gain by

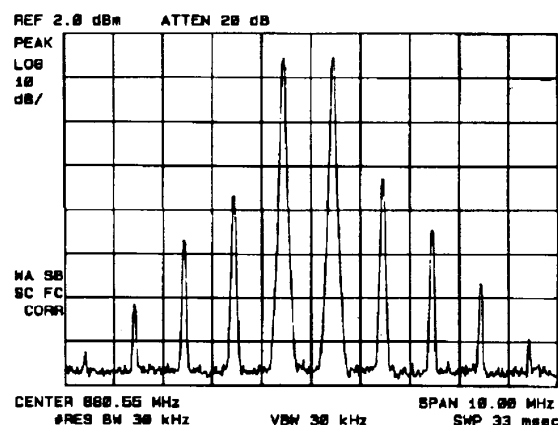


Figure 4: Two-tone test showing typical intermodulation distortion in a non-linear amplifier

a factor known as the *stability margin*, typically 10-20dB, for unconditional stability. The achievable antenna isolation therefore limits the maximum repeater gain.

$$I > G + SM \quad (1)$$

where

I = Antenna isolation (dB)  
G = Repeater's electrical gain (dB)  
SM = Stability Margin (dB)

OFRs are usually positioned on a line connecting the donor transmitter and the area to be boosted. This configuration minimises multi-path like interference effects [3] and leads naturally to the use of directional antennas, with the receiver's antenna pointing towards the donor transmitter and the retransmit antenna pointing towards the area to be boosted. It is the directivity of the antennas that provide the necessary transmitter/receiver isolation in current OFRs. A typical figure for the isolation between two panel antennas mounted on a single pole, vertically separated by 30 feet is 64dB, however 80dB is not unreasonable given additional shielding [4]. Assuming a 15dB stability margin, a maximum active gain of 65dB results.

Few attempts at increasing antenna isolation have been made, apart from improving antenna positioning and shielding. A cancellation system described in [5] was adopted by Plessey in their military single-channel repeater *Groundsat*, however this is only suited to single, angle-modulated channels.

Sampling and store-and-forward techniques [6] which increase transmitter/receiver isolation by operating the

receiver and transmitter alternately, switching at a rate greater than the Nyquist frequency, are impractical in wideband systems. It is also difficult to prevent the transmitted spectrum of a sampling repeater from falling into adjacent channels, thereby reducing much of the spectral efficiency benefits of OFRs.

Zeger [7] describes a continuous cancellation system that uses a single omni-directional antenna with transmit and receive sides isolated by means of a hybrid. The isolation is then further increased by summing a complex weighted portion of the transmitter's output in antiphase with the receiver's input, thus cancelling 'direct' interference. The repeater operated over a fairly narrow bandwidth (100kHz) and used a pilot added to the transmitter's output, thus reducing the repeater's transparency to the rest of the network.

## The Solution

A cell enhancer which offers a combination of high-gain and high output power with extremely good linearity is currently under development at the University of Bristol. The prototype repeater offers an active gain of at least 100dB over a bandwidth of several MHz. A linearised broadband amplifier is combined with a novel system for reducing the effect of the damaging mutual coupling between the transmitter and receiver, resulting in a transparent repeater that offers users greater flexibility and functionality than current designs.

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